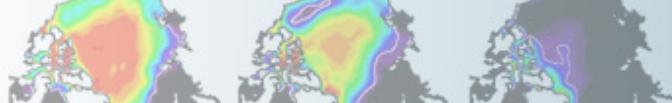


# Balancing processes, resolution and ensembles in Earth System Models

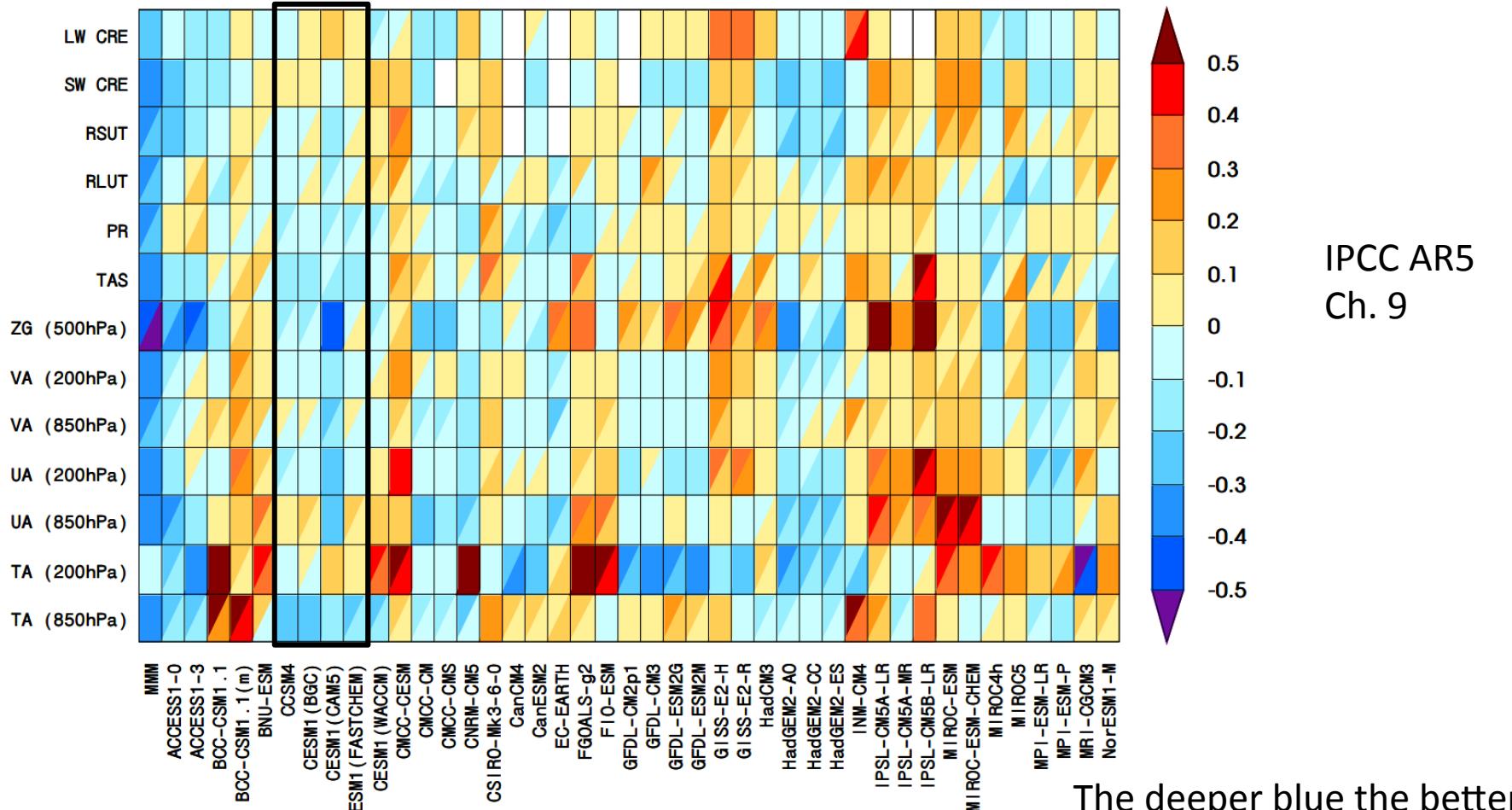
Jean-François Lamarque

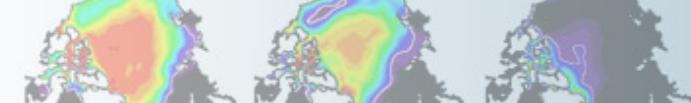
CESM Chief Scientist

National Center for Atmospheric Research



# CESM CMIP5 models

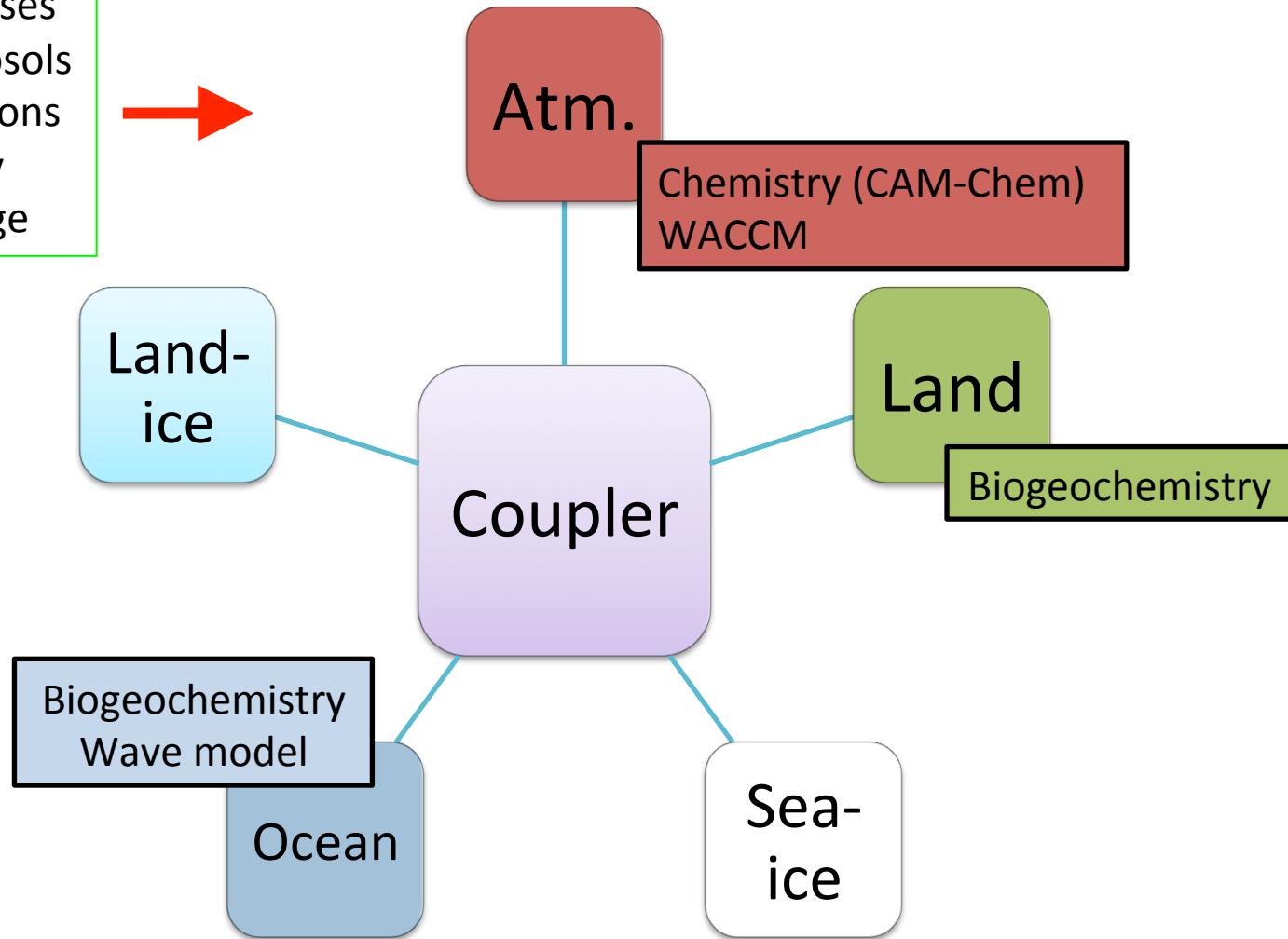




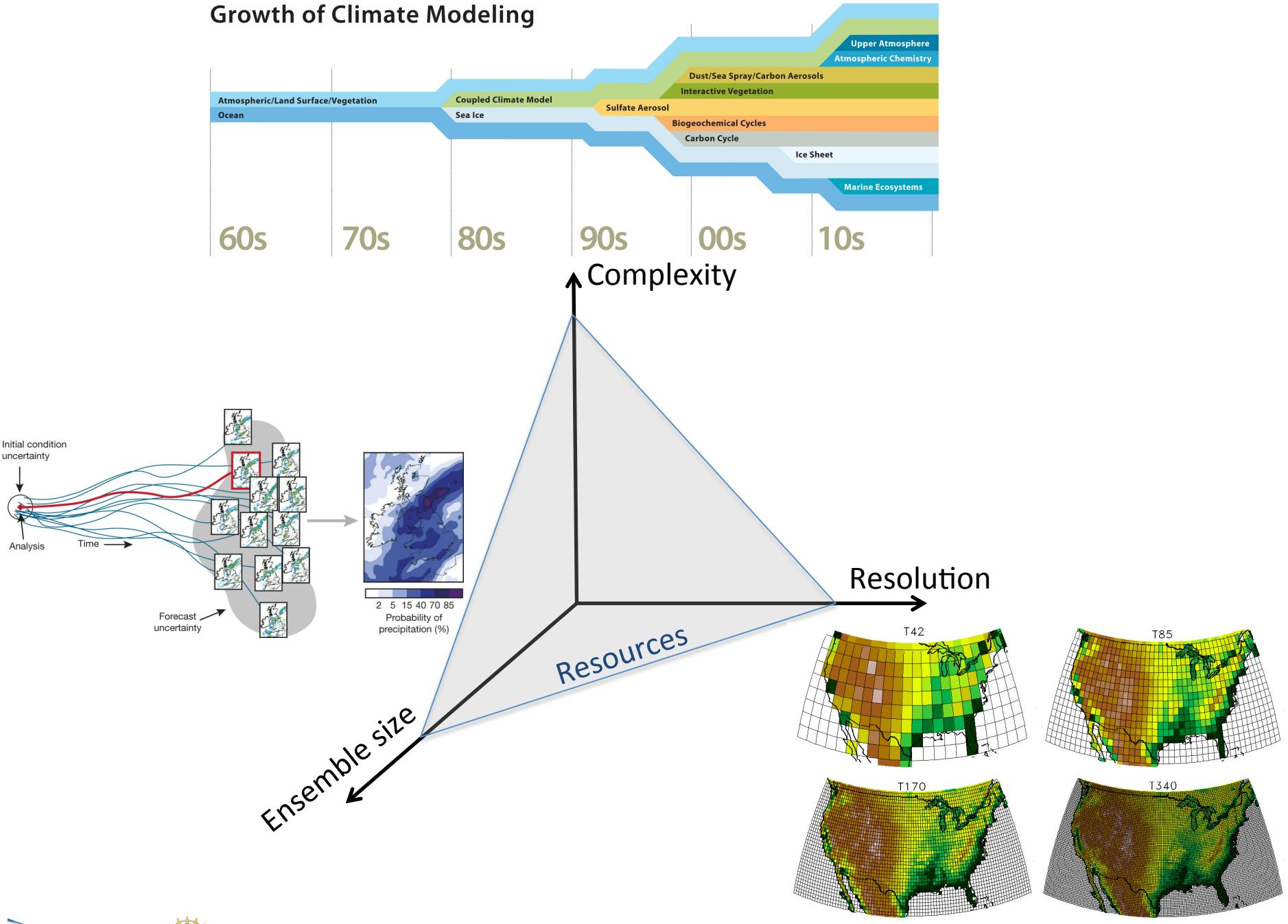
# Components of CESM

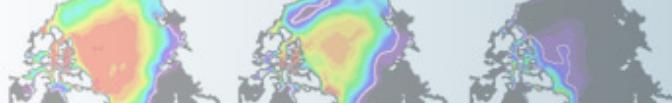
## Forcings:

- Greenhouse gases
- Manmade aerosols
- Volcanic eruptions
- Solar variability
- Land-use change



# Growth of Climate Modeling

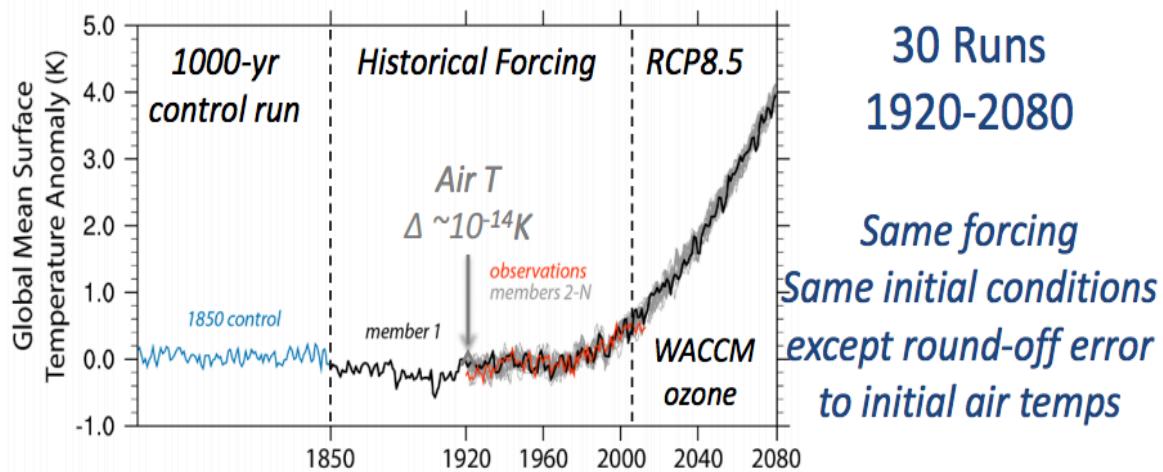




# ENSEMBLES

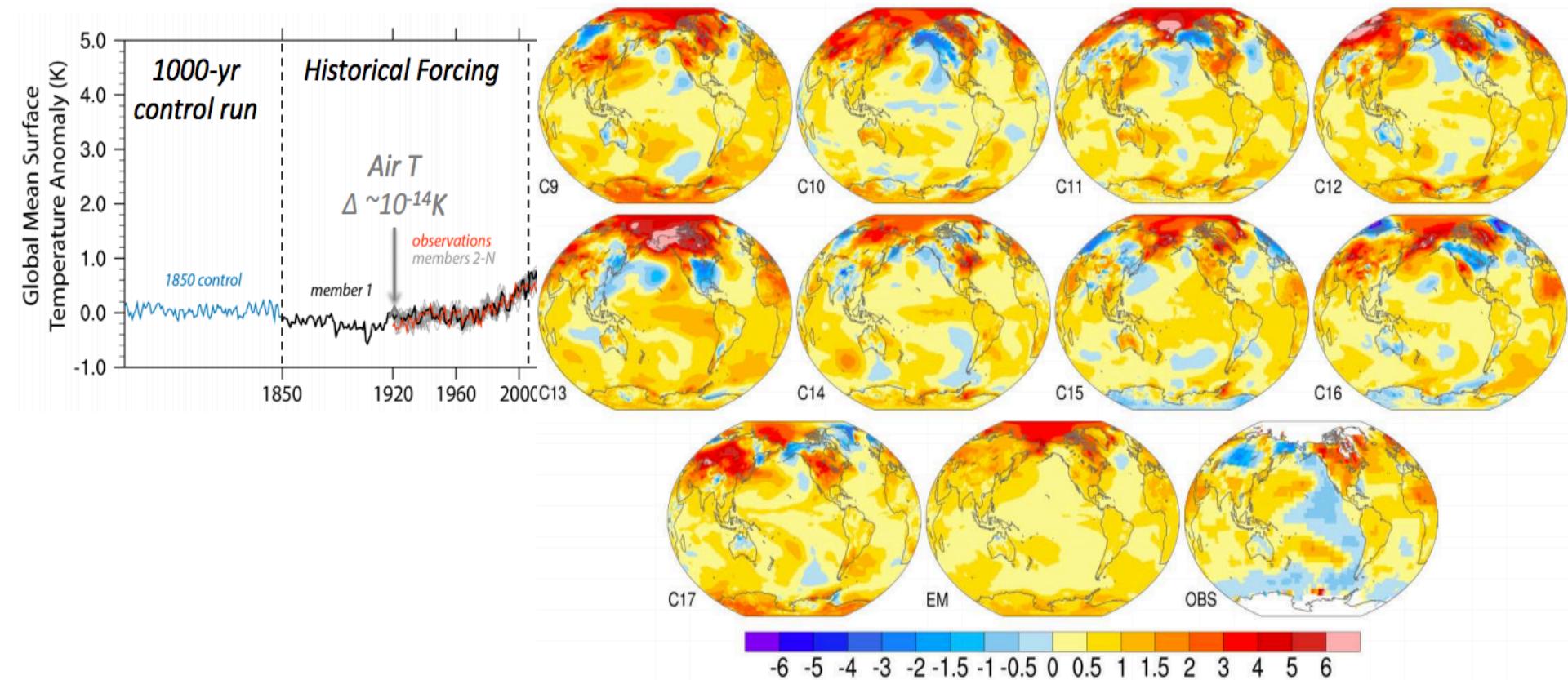


# Internal variability and ensemble





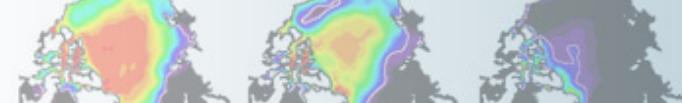
# Internal variability and ensemble



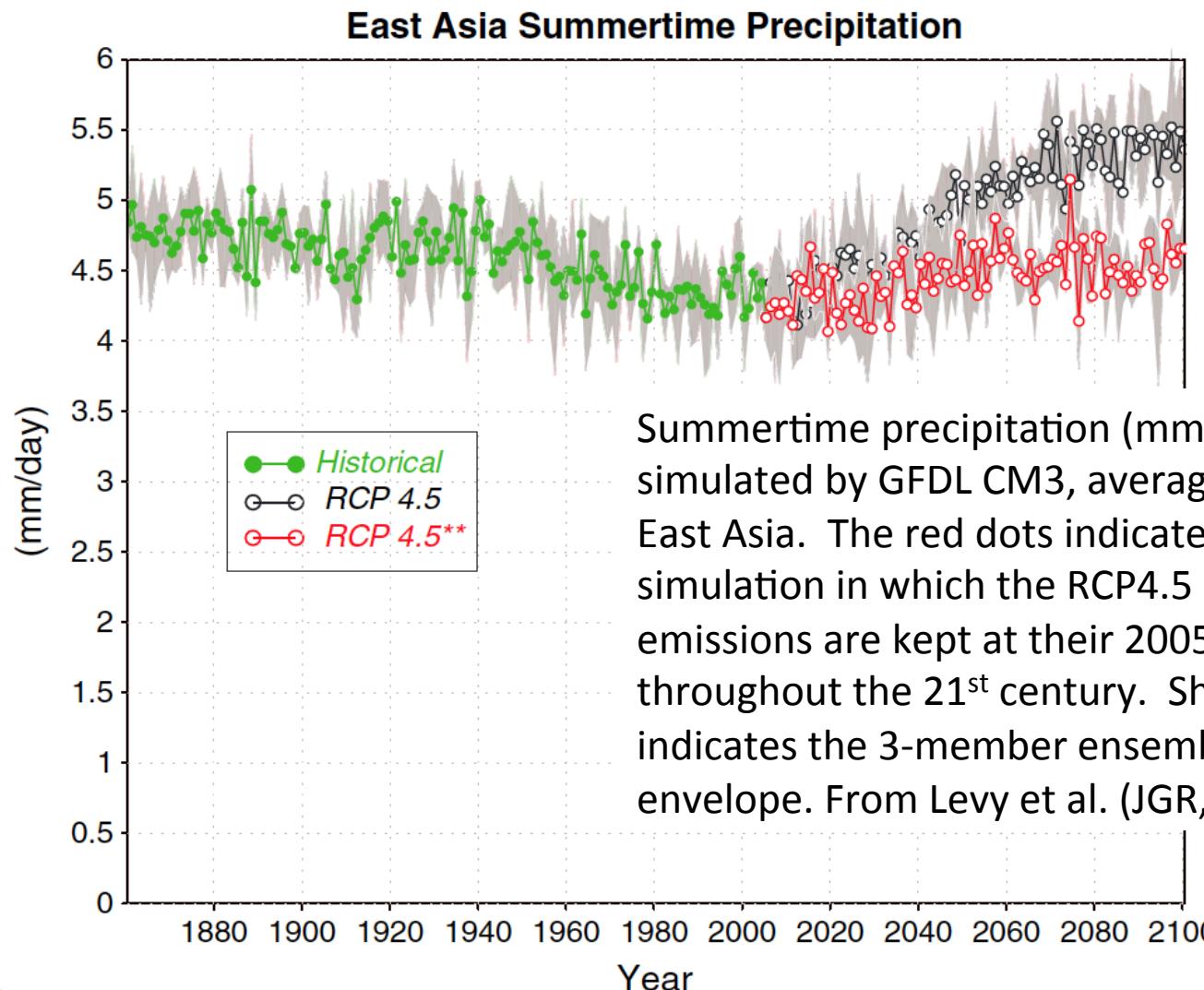
Panels show 1979–2012 DJF surface temperature trends for 9 ensemble members, the ensemble mean, and observations.



# PROCESSES



# Climate impacts of SLCFs

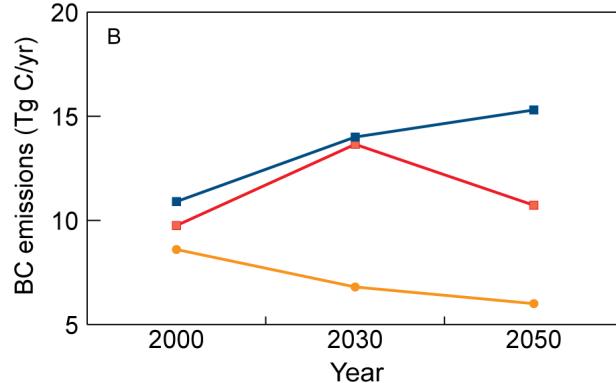
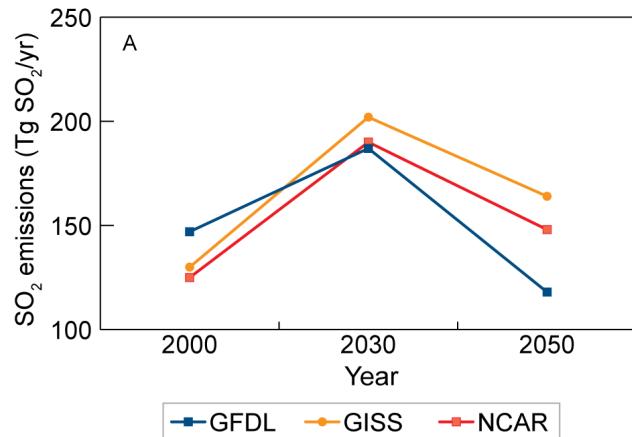


Summertime precipitation ( $\text{mm} \cdot \text{day}^{-1}$ ) as simulated by GFDL CM3, averaged over East Asia. The red dots indicate the simulation in which the RCP4.5 aerosol emissions are kept at their 2005 level throughout the 21<sup>st</sup> century. Shading indicates the 3-member ensemble envelope. From Levy et al. (JGR, 2013).



# Modeling SLCFs in CMIP3 and CMIP5

Emissions from  
SRES A1B scenario

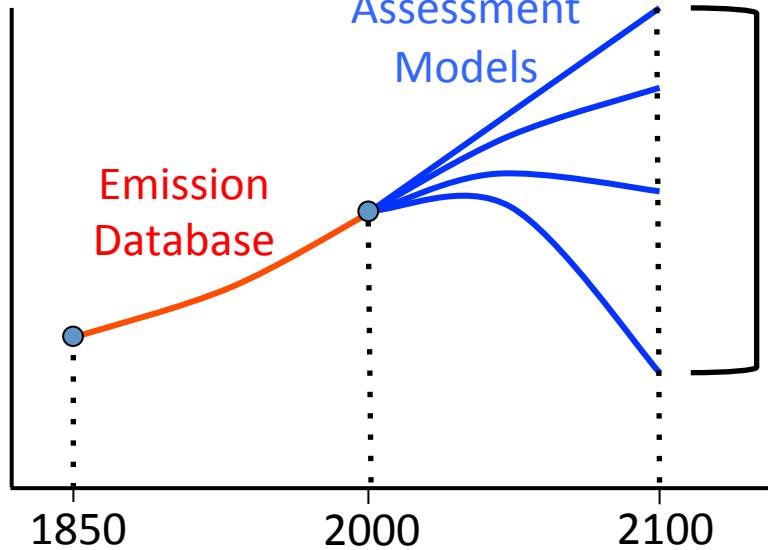


Shindell et al., JGR, 2008

Emissions (anthropogenic & biomass burning)

Integrated  
Assessment  
Models

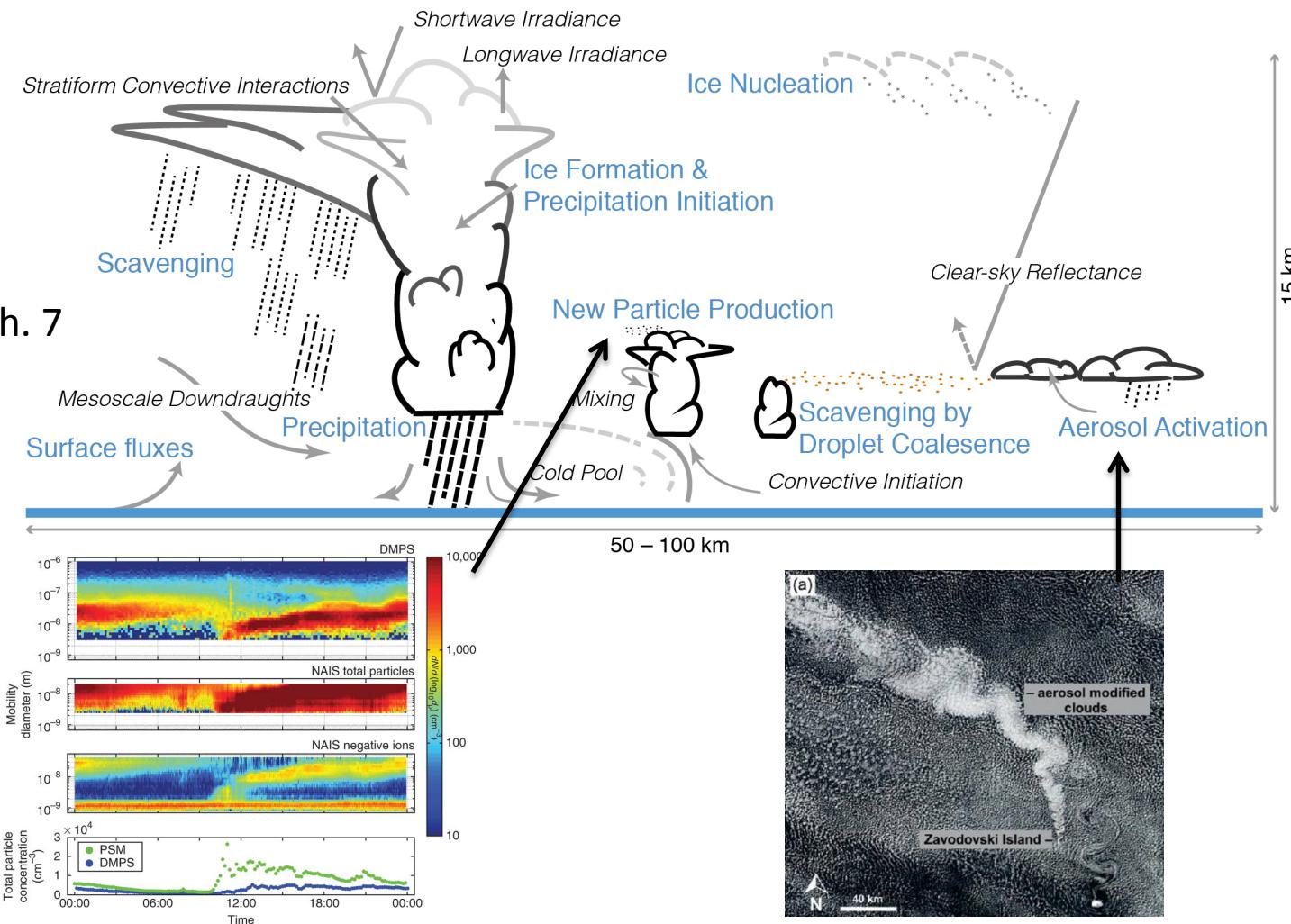
RCPs



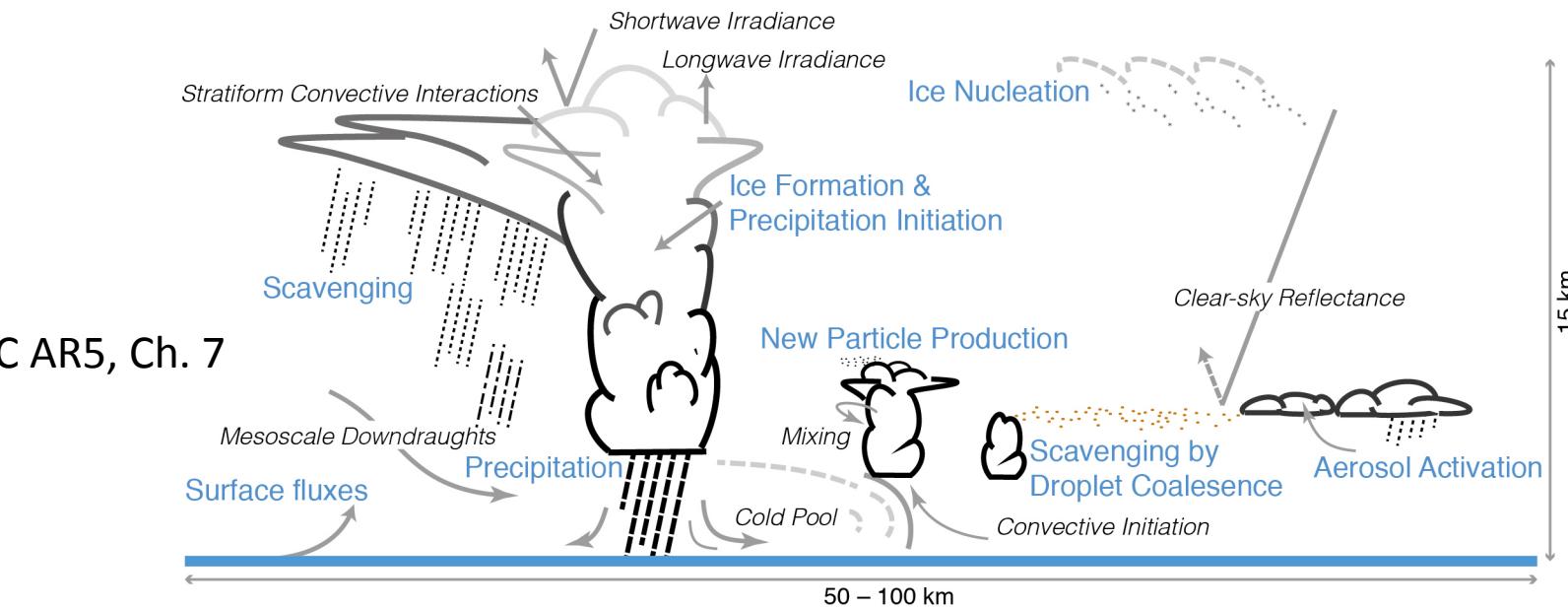
Lamarque et al., 2010

# CMIP3 -> CMIP5: aerosols conc. -> emissions

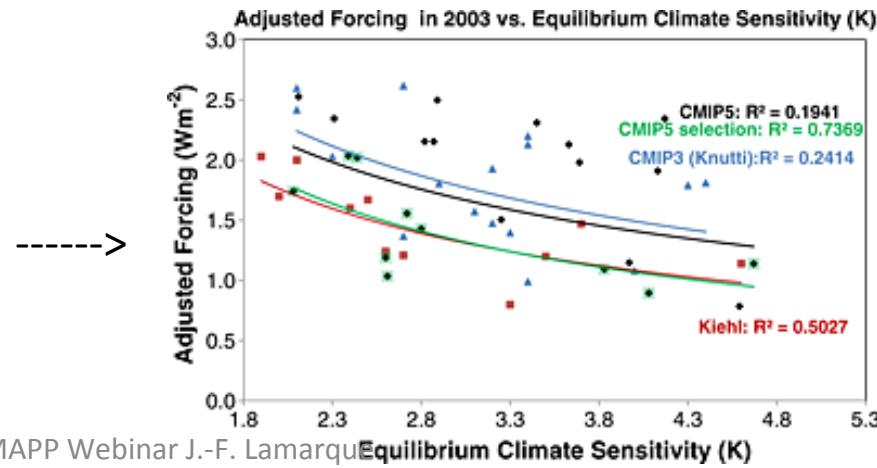
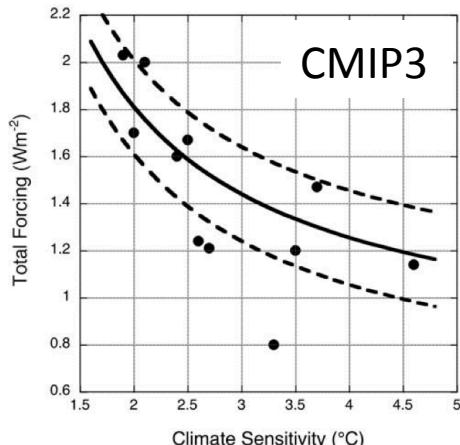
IPCC AR5, Ch. 7



# CMIP3 -> CMIP5: aerosols conc. -> emissions



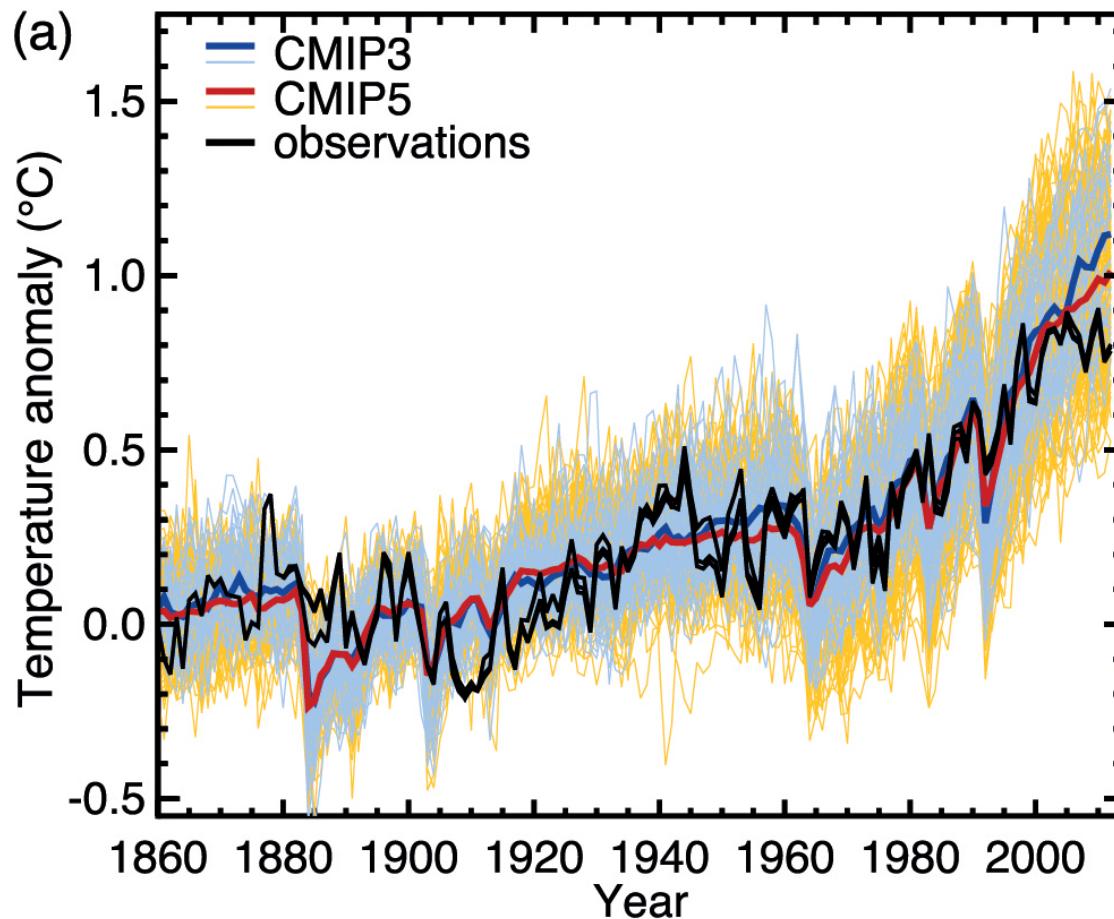
Kiehl, 2007



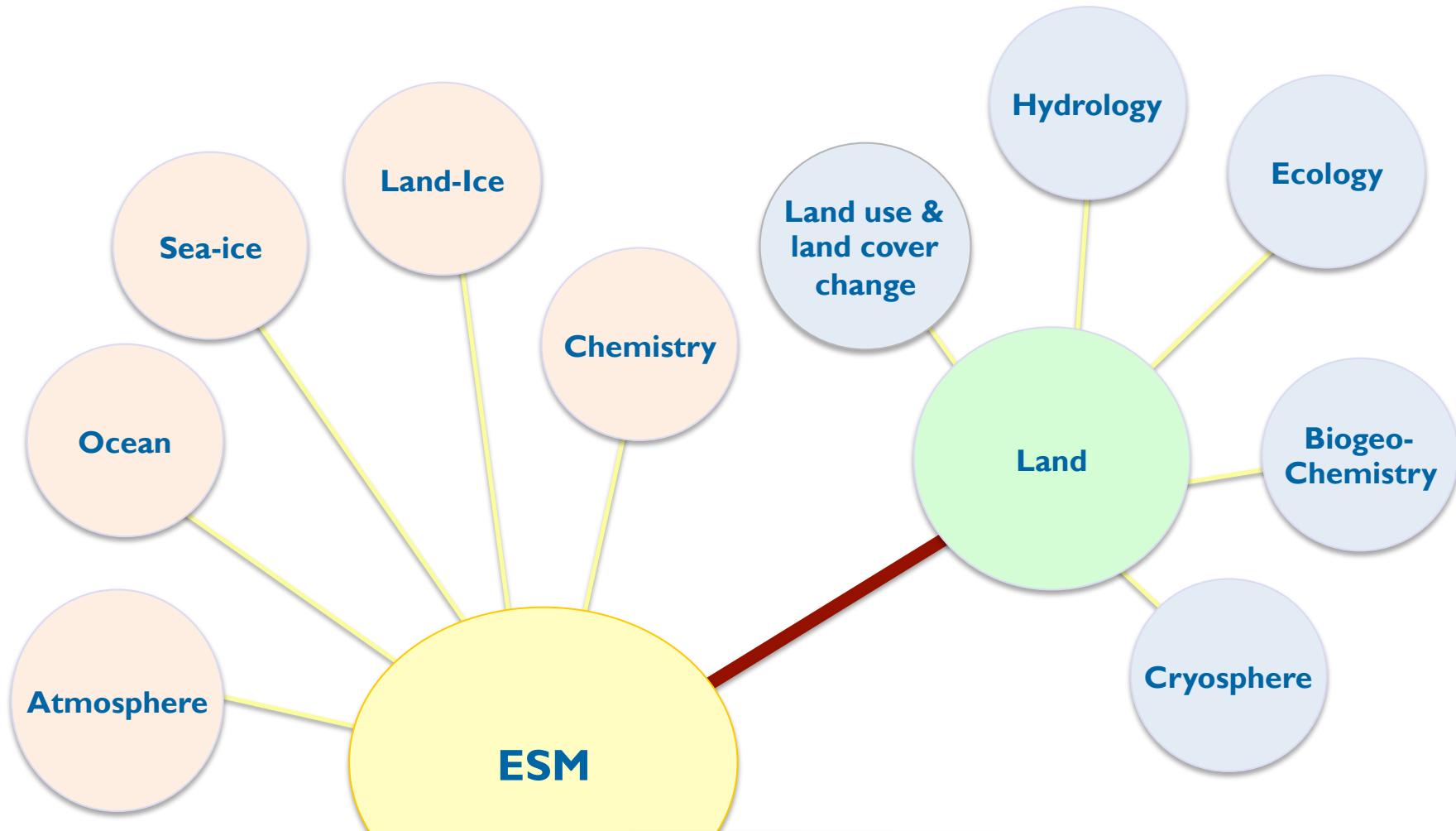
Forster et al., 2013



# CMIP3 -> CMIP5: aerosols conc. -> emissions

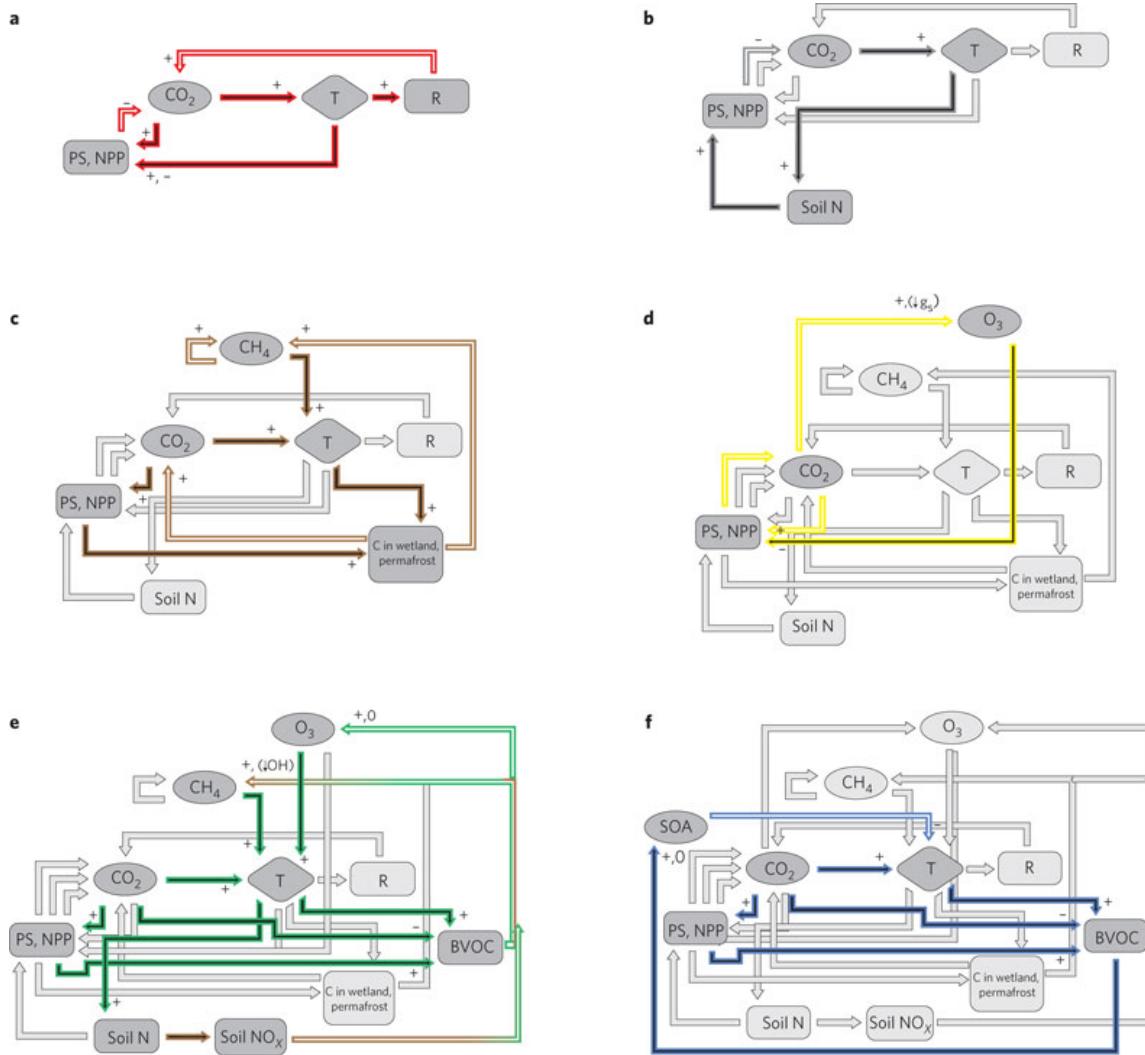


# Using all research communities to improve process representation and evaluation: the case of the Land Model





# Biogeochemistry feedbacks



Arneth et al., 2010



# How do we factor in evolution?

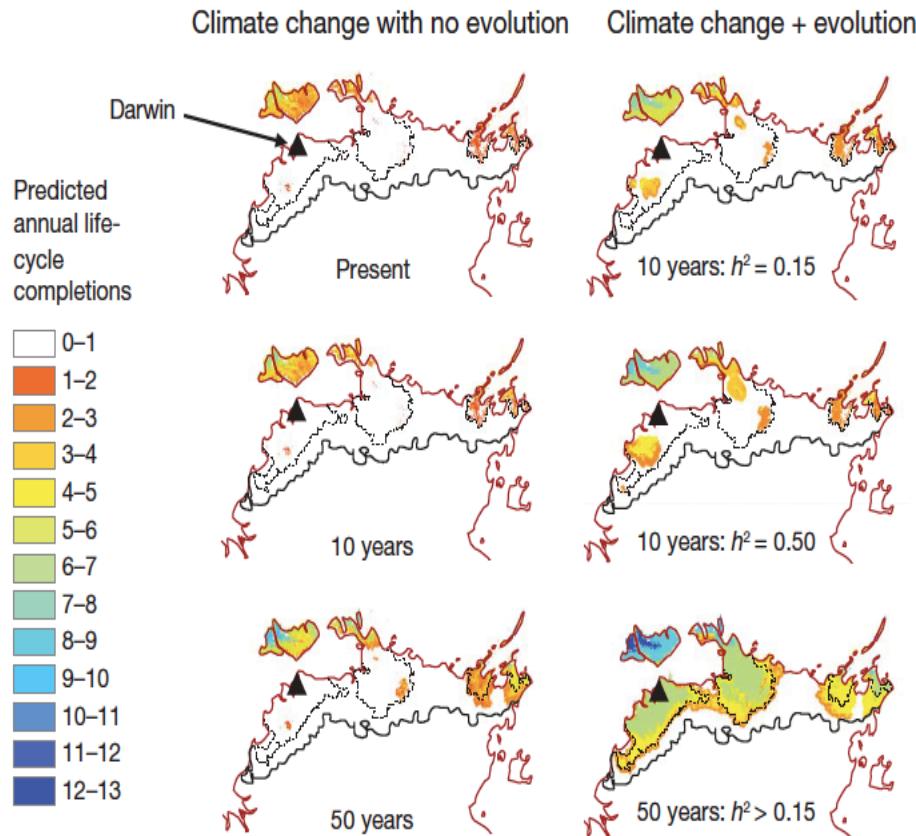


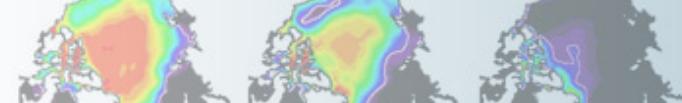
Figure 1 | Potential effect of evolution in egg desiccation resistance on life-cycle completions of the mosquito *Aedes aegypti* in the region around Darwin, Australia. Predictions are based on a mechanistic model of mosquito development with egg desiccation resistance evolving as a threshold trait determined by the length of time that eggs are exposed to air after water in breeding sites has evaporated. Modified with permission from ref. 7.

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# Summary

- Bringing new processes allows for a more physically/chemically/biologically observable Earth System Model (requires link to external communities)
- Ensembles are a key component to our understanding of the Earth System and how it might respond to forcing
- Significantly impacts the balance of resolution with existing resources



# Summary

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- Ens unc mig
- Sigr wit

